Effects of supplement amount, with or without calcium salts of fatty acids, on growth performance and intake behavior of grazing *Bos indicus* bulls

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ABSTRACT: This study evaluated the effects of 2 supplement dry matter (**DM**) amounts, with or without calcium salts of fatty acids (**CSFA**), on growth performance, supplement and water intake behavior of grazing beef bulls. On day 0, 32 Nellore bulls were ranked by initial body weight (**BW**; 318 ± 11.2 kg), and then, randomly assigned to treatments ($n = 8$ bulls/treatment), in a 2 × 2 factorial design, which consisted of energy-based supplement DM amount of 0.3 (**SP03**) or 1.0 (**SP1**) % of BW with (**+**) or without (**−**) CSFA fortification (90 to 100 g/bull daily). During the experiment (98 d), all bulls were managed as single group and rotated between 2 *Brachiaria* pastures every 9 to 11 d. Each pasture contained an individual electronic data capture system with 2 feed bunks/treatment and 1 water through to determine individual supplement DM and water intake, as well number of visits, time spent at the feeder/waterer, and intake per visit (**IPV**). A supplement effect was detected ($P = 0.02$) for final BW. Bulls supplemented at 1.0% of BW, regardless of CSFA inclusion amount, were heavier at the end of the experiment vs. SP03 bulls. Overall average daily gain (ADG) was greater ($P = 0.05$) for SP03+ vs. SP03− bulls, and did not differ ($P = 0.87$) between SP1+ vs. SP1− bulls. No supplement amount, CSFA, or supplement amount × CSFA effects were observed ($P \geq 0.13$) for supplement and water intake behavior, number of visits to the feeder or IPV. However, SP1 bulls spent ($P = 0.05$) more time at the feeder than SP1+ bulls, whereas bulls supplemented with CSFA tended ($P = 0.10$) to consume less water (as % of BW) than cohorts supplemented without CSFA. In summary, CSFA fortification into 0.3% of BW supplements increased ADG when compared with cohorts not offered CSFA. On the other hand, no benefits were observed when CSFA was included into 1.0% of BW supplements, primarily due to the lower than projected supplement, and consequently, CSFA intake. Moreover, CSFA fortification tended to reduced water intake, demonstrating a potential of this technology to increase performance of beef herds, while maintaining the utilization of natural resources.

Key words: calcium salts of fatty acids, energy level, grazing bull, performance, water intake

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INTRODUCTION

In feedlot cattle, the major benefits of fat supplementation have been the increased energy density of the diet and improved feed efficiency, primarily due to an alteration on dry matter intake (**DMI**) and rumen fermentation parameters (NASEM, 2016; Hales et al., 2017). In Brazil,

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the primary fat feedstuffs included in feedlot cattle diets are cottonseed byproducts and calcium salts of fatty acids (**CSFA**; Pinto and Millen, 2019), accounting for 70% and 10% of these feedstuffs, respectively. Conversely, grazing ruminants are usually offered limited amounts of fat supplementation (Hess et al., 2008). Most studies evaluated fat supplementation strategies for cattle grazing temperate forages (Hess et al., 2008), whereas data evaluating the effects of fat supplementation on performance of beef cattle grazing warm-season forages is scarce.

Supplementation with CSFA improved average daily gain (ADG) (Rosa et al., 2013) and feed efficiency (Barducci et al., 2015) for feedlot beef cattle. Moreover, CSFA supplementation also positively impacted productive parameters of dairy cattle (Batistel et al., 2017) and reproductive performance of *Bos indicus* beef cows (Lopes et al., 2009, 2011). Conversely, we are unaware of other studies evaluating the effects of CSFA supplementation on growth performance of grazing growing beef cattle. Additionally, it is important to understand the effects of CSFA on water intake, given the present environmental concern regarding the effects of beef production on the utilization of natural resources and the ultimate goal of increasing productivity while preserving these resources (Ahlberg et al., 2018; Zanetti et al., 2019). Based on this rationale, we hypothesized that CSFA supplementation to grazing beef bulls would increase performance without impacting water intake of the herd. Therefore, our objective was to evaluate the effects of supplement dry matter (**DM**) amount (0.3% or 1.0% of body weight [**BW**]) with or without CSFA fortification on growth performance, supplement and water intake behavior of grazing Nellore bulls.

MATERIALS AND METHODS

This experiment was conducted at a commercial beef operation (Fazenda São Joaquim), located in Jandaia, Goiás, Brazil (17°02′55″S, 50°08′46″W, and elevation of 637 m) from November 2018 to February 2019. Average temperature from November 2018 to February 2019 was 27, 26, 25, and 24 °C, respectively. Average humidity was 75%, 81%, 81%, and 78%, whereas total rainfall during the period of the study was 178, 248, 244, and 197 mm, respectively. All bulls utilized herein were cared for in accordance with the practices outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Training (FASS, 2010).

Animals and Diets

On day 0 of the study, 32 Nellore (*B. indicus*) bulls were ranked by initial shrunk (BW; after 16 h of feed and water restriction; 318 ± 11.2 kg; initial age = 13 ± 2.1 mo) and randomly assigned to treatments in a 2 × 2 factorial design. Major factors consisted of individual DM supplementation at 0.3% or 1.0% of BW (SP03 and SP1, respectively), whereas the minor factors were the inclusion or not of CSFA into the supplements. Therefore, all possible treatment combination were: 1) DM supplementation at 0.3% of BW without CSFA fortification (**SP03−**; $n = 8$ bulls); 2) DM supplementation at 0.3% of BW with CSFA fortification (**SP03+**; $n = 8$ bulls); 3) DM supplementation at 1.0% of BW without CSFA fortification (**SP1−**; $n = 8$ bulls), and 4) DM supplementation at 1.0% of BW with CSFA fortification (**SP1+**; $n = 8$ bulls). Supplements used for the 0.3% (Boca Cheia) and 1.0% (Vanguarda) supplementation amount were obtained from Campo Nutrição Animal (Goiânia, GO, Brazil), whereas the CSFA source (Nutrigordura) was obtained from Nutricorp (Araras, SP, Brazil). The complete composition and nutritional profile of each supplement are described in Table 1, whereas the complete mineral composition of SP03 and SP01 supplements is reported in Table 2. The CSFA used herein was a soybean-based product (iodine value = 125; fatty acid profile of the supplement was approximately 15% C16:0, 4% C18:0, 25% C18:1 *n*-9, 38% C18:2 *n*-6, and 3% C18:3 *n*-3) and was included at equivalent amounts to provide 90 to 100 g of CSFA per bulls daily at the beginning of the experiment.

In order to avoid any potential pasture effect on growth performance and supplement intake behavior of the herd, all bulls were managed as a single group but rotated between 2 *Brachiaria brizantha* cv. Marandu paddocks (2 ha per paddock). The pasture rotation was performed every 9 to 11 d, based on the herbage height of the paddock, throughout the experimental period (98 d). Bulls were provided *ad libitum* access to water and forage throughout the study.

Supplements were offered daily (0800 hours), but supplementation DM amount was adjusted weekly using weekly BW collected from each bull. Moreover, a + 10% adjustment of the amount of supplement to be offered was taken into account

Table 1. Composition and nutritional profile of the supplements offered to the herd during the entire experiment[1,2]

Item, g/d	SP03−	SP03+	SP1−	SP1+
Ground corn	621	531	2,406	2,316
Soybean meal	135	135	372	372
Urea	27	27	32	32
Mineral–vitamin mix	117	117	168	168
Calcium salts of fatty acids	—	90	—	90
Nutritional profile, g/d				
Dry matter	809	814	2,691	2,709
Crude protein	262	234	702	626
Neutral detergent fiber	60	35	180	138
Acid detergent fiber	49	23	137	114
Ether extract	24	63	129	182
Total digestible nutrients[3]	636	648	2,126	2,151
Net energy for maintenance[4]	1.67	1.73	5.62	5.69
Net energy for gain[4]	1.14	1.18	3.82	3.87

[1]Samples were collected at the beginning of the experiment.

[2]SP03− = supplementation of 0.3% of BW without CSFA fortification; SP03+ = supplementation of 0.3% of BW with CSFA fortification; SP1− = supplementation of 1.0% of BW without CSFA fortification; SP1+ = supplementation of 1.0% of BW with CSFA fortification.

[3]The total digestible nutrients concentrations were calculated according to equations described by Weiss et al. (1992).

[4]The net energy for maintenance and for gain concentrations were calculated with the equations reported by NASEM (2016).

Table 2. Mineral composition of the 0.3% and 1.0% of BW supplements offered throughout the experimental period (days 0 to 98)[1]

	Supplements[2]	
Mineral	SP03	SP1
g/kg		
Magnesium	3.5	2.2
Sulfur	15.0	32.0
Sodium	11.0	17.6
Chloride	18.0	29.0
Calcium	40.0	15.0
mg/kg		
Phosphorus	6,000	3,500
Copper	81.0	32.5
Zinc	300.0	120.0
Iron	280.0	49.0
Manganese	57.0	22.5
Iodine	5.0	2.0
Cobalt	5.4	2.1
Selenium	1.5	0.6

[1]Throughout the experimental period, supplements were offered on a daily basis in a manner to ensure ad libitum consumption.

[2]SP03 = Boca Cheia (Campo Nutrição Animal, Goiânia, Goiás, Brazil) and SP1 = Vanguarda (Campo Nutrição Animal).

for day-to-day variation of intake and also to allow orts, so the bulls would be able to consume adequate amounts throughout the experimental period. When necessary, supplement refused prior to each morning feeding was removed and the feed bunk cleaned to provide a fresh supplement every day.

Individual Data Capture System

On d −21 of the study, bulls were allocated to paddocks to get acclimated with the individual electronic feeder and waterer data capture systems (Intergado; Contagem, Minas Gerais, Brazil). This system was composed of 1 water through, 8 feed bunks (2 bunks/treatments; 4 bulls/bunk). Following the randomization on day 0 of the study, bulls within treatments were assigned to specific feed bunks throughout the 98-d experimental period. Additionally, a similar system was built in the water source, in a manner that the intake would be continuously recorded. Full description of the equipment for supplement and water parameters measurements and system validation for beef cattle were described by Chizzotti et al. (2015) and Zanetti et al. (2019), respectively. The system recorded the duration of each visit, number of daily visits, and supplement and water intake by recording each bull ID, bunk number (for supplement only), and individual amount of feed and water consumed on a daily basis (24-h period). Individual supplement and water intake was continuously recorded throughout the experimental period (days 0 to 98). All data were exported to the Intergado Web Software and reports were generated on a daily basis to detect any malfunctioning of the system. Additionally, a scale for BW measurement was built at the water source that continuously weighed the bulls during the experimental period and allowed the aforementioned weekly supplement offer adjustment.

Sampling

Individual shrunk BW of bulls was collected on days 0 and 98 after 16 h of feed and water withdrawal, and used to calculate the BW change (final minus initial BW) and ADG during the experiment.

Evaluation of individual supplement DMI, water intake, as well as frequency of visits to the feeder and water source were determined on a weekly basis. The cumulative 7-d period was used as repeated measures of the treatments. Individual treatment intake was evaluated on a daily basis throughout the experimental period to ensure ad libitum supplement availability. The frequency of visits to the feeder and water source was calculated based on the total number of visits within each specific week of the experimental period. Time spent at the feeder and at the water source (minutes/day) was also evaluated herein based on the information collected at the equipment and uploaded into the Intergado Web Software. Additionally, based on the resulting intake (supplement and water), intake per visit (**IPV**) was determined, whereas results were averaged and analyzed on a weekly basis, as well as reported as kg or liter per day for supplement and water, respectively.

Throughout the experimental period, samples were collected every 20 d for determination of the nutritional profile of the forage, whereas supplement samples were collected at the beginning and end of the experiment. Forage samples were collected by hand-clipping to ground level inside a 1 m^2 quadrant (10 random location within paddocks), as described by Fieser et al. (2007). Calculation of forage and supplement total digestible nutrients concentrations was performed according to Weiss et al. (1992), and samples of forage and supplement analyzed in duplicates by wet chemistry procedures for concentrations of crude protein (method 984.12; AOAC, 2006), acid detergent fiber (**ADF**; method 973.18 modified for use in an Ankom-200 fiber analyzer; Ankom Technology Corp., Fairport, NY; AOAC, 2006), neutral detergent fiber (**NDF**; Van Soest et al., 1991; modified for use in an Ankom-200 fiber analyzer; Ankom Technology Corp.), and cellulose (Goering and Van Soest, 1970). The hemicellulose content of the samples was calculated as the subtraction of NDF and ADF, whereas the lignin content was calculated as the difference between ADF and cellulose. Moreover, ether extract content was determined following the procedures of AOAC (2006) and the net energy for maintenance and gain were calculated according to equations described by NASEM (2016). The nutritional profile of the supplements and forage is reported in Tables 1 and 3, respectively. Concurrently with forage sampling for nutritional analysis, forage DM availability was measured according to Fieser et al. (2007). Forage DM availability was close to or above 2,000 kg DM/ha (data not shown), which is considered the minimal DM amount to provide ad libitum forage DMI for grazing beef cattle (Minson, 1990).

Statistical Analysis

For all analyses performed herein, animal was considered the experimental unit. All data were analyzed using the PROC MIXED procedure of SAS (Version 9.4; SAS Inst. Inc., Cary, NC, USA) and the Satterthwaite approximation to determine the denominator df for the test of fixed effects. The model statement used for BW change and ADG contained the fixed effects of supplement DM amount, CSFA inclusion, and the resulting interaction. Data were analyzed using bull(supplement × CSFA) as random variable. The model statement used for supplement or water intake, number of visits to the feeder or water source, I/V, and time spent at the feeder and at the water source (min/d) contained the fixed effects of supplement DM amount, CSFA inclusion, week, and all resulting interactions. Data were analyzed using bull(supplement × CSFA) as random variable. The specified term for the repeated statement was week, whereas bull(supplement × CSFA) was the subject. The autoregressive 1 covariance structure was selected as it provided the smallest Akaike information criterion. All results are reported as

Table 3. Nutritional profile of the forage (*Brachiaria brizantha* cv. Marandu) offered to the herd throughout the experimental period (98 d)[1]

	Day of the study				
Item	0	20	40	60	80
Dry matter, %	83.7	77.2	77.9	80.0	74.9
Crude protein, % DM	11.5	13.6	13.2	10.5	11.5
Neutral detergent fiber, % DM	58.1	64.4	62.0	65.9	63.9
Acid detergent fiber, % DM	38.2	38.3	37.6	41.5	37.8
Hemicellulose, % DM[2]	19.9	26.1	24.4	24.4	26.1
Cellulose, % DM	12.1	19.3	18.1	15.9	19.4
Lignin, % DM	7.8	6.8	6.3	8.5	6.7
Ether extract, % DM	4.5	3.6	3.9	3.7	3.6
Total digestible nutrients, % DM[3]	47.0	46.1	47.3	44.1	49.2

[1]Samples were collected every 20 d.

[2]Hemicellulose was calculated as the subtraction between neutral and acid detergent fiber.

[3]Total digestible nutrients were calculated according to equation proposed by Weiss et al. (1992).

least square means and separated using the PDIFF. Significance was set at $P \leq 0.05$ and tendencies were denoted if $0.05 < P \leq 0.10$. Results are reported according to the main effects if no interactions were significant or according to the highest-order interaction detected.

RESULTS AND DISCUSSION

During a significant portion of the year, warm-season forages often do not have the balanced nutrient composition and/or availability to optimize rumen environment and fiber digestion, intake, and performance (Detmann et al., 2014). Hence, energy and protein supplementation are required to optimize cattle performance during these critical periods (McDowell and Arthington, 2005). Few studies have evaluated the potential of CSFA as an alternative to improve the performance of cattle grazing warm-season forages. Overall and throughout the experimental period, forage nutritional composition (Table 3) was adequate to promote growth of the animals enrolled to the present study.

Two SP03− bulls were removed from the statistical analysis as these bulls were not visiting the feeder. Nonetheless, the weekly supplementation amount offered to bulls was adjusted on a weekly basis to account for the removal of these 2 bulls. Hence, all statistical analysis for the SP03− group contained 6 experimental units vs. 8 experimental units for SP03+, SP1−, and SP1+ groups.

Growth Performance

Initial BW did not differ ($P \geq 0.85$) among treatments (Table 4), demonstrating that before the beginning of the experiment, bulls were under the same management and properly randomized among treatments. Nonetheless, a supplement DM amount effect was detected ($P = 0.02$) for final BW. Bulls supplemented at 1.0% of BW (regardless of CSFA inclusion) were heavier ($P = 0.02$) at the end of the experiment compared to bulls supplemented at 0.3% of BW (Table 4). A supplement × CSFA interaction was observed for ADG ($P = 0.04$). Overall ADG was 108 g greater ($P = 0.05$) for SP03+ vs. SP03− bulls, whereas no differences were observed between SP1− and SP1+ bulls ($P = 0.87$; Figure 1). Additionally, bulls supplemented at 1.0% of BW had a greater ADG compared to those supplemented at 0.3% of BW (Table 4). Effects of CSFA inclusion were not ($P = 0.23$) observed for overall ADG (Table 4).

Hess et al. (2008) suggested that the optimal inclusion rate for supplemental fat should be <3% of diet DM to maximize the use of forage-based diets, ≤2% of diet DM to prevent the forage substitution with the intake of fat supplements, and should not exceed 4% of diet DM if the goal of the operation is to increase dietary DE intake with fat supplements. Nonetheless, the aforementioned review focused on lipid feedstuffs commonly used on U.S. beef cattle operations (i.e., tallow, glycerin, soybean oil, and corn oil). In Brazil, the major lipid ingredients used in feedlot settings are cottonseed byproducts and CSFA, with the latter accounting for 10% of the utilization (Pinto and Millen, 2019). Barducci et al. (2015) demonstrated that CSFA supplementation to feedlot cattle improved feed efficiency compared to nonsupplemented and cottonseed byproduct-supplemented (lipid source) cohorts. Moreover, Rosa et al. (2013) reported a positive effect of CSFA supplementation on ADG, feed and protein efficiency of feedlot cattle. Nonetheless, it is important to mention that no other study has evaluated the utilization of CSFA in other production settings, such as performance of growing bulls on pasture. Considering that CSFA are typically more expensive than common energy sources (i.e., whole cottonseed), the inclusion of CSFA in a supplementation program to grazing cattle would

Table 4. Growth performance of Nellore bulls offered DM supplementation at 0.3% or 1.0% of BW with or without CSFA fortification from days 0 to 98[1]

	SP03		SP1			*P*-value		
Item2	SP03−	SP03+	SP1−	SP1+	SEM	Supplement	CSFA	Supplement × CSFA
Initial BW, kg	317	318	318	318	4.2	0.89	0.85	0.96
Final BW, kg	396	410	426	428	9.7	0.02	0.44	0.57
BW change, kg	79	92	108	110	6.5	0.001	0.36	0.50
ADG, kg/d	0.81[a]	0.92[b]	1.11[c]	1.12[c]	0.041	0.001	0.23	0.04

[abc]Within a row, means without a common superscript differ ($P < 0.05$).

[1]SP03− = supplementation of 0.3% of BW without CSFA fortification; SP03+ = supplementation of 0.3% of BW with CSFA fortification; SP1− = supplementation of 1.0% of BW without CSFA fortification; SP1+ = supplementation of 1.0% of BW with CSFA fortification.

[2]Throughout the experimental, data were collected through an electronic data capture system (Intergado; Contagem, Minas Gerais, Brazil).

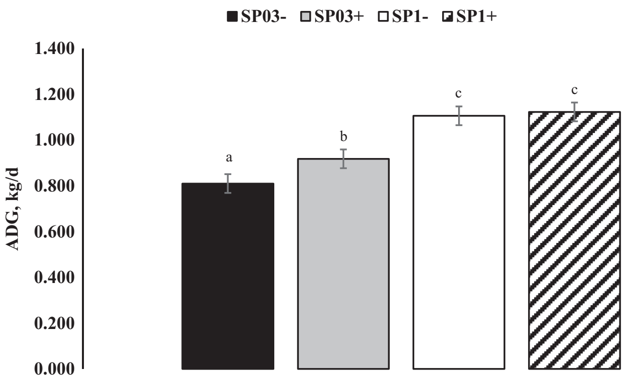

Figure 1. Average daily gain (kg/day) of bulls offered 2 supplementation DM amounts (0.3 or 1.0% of BW) with or without CSFA fortification from days 0 to 98. A supplement × CSFA interaction was observed for overall ADG ($P = 0.04$; SEM = 0.041). Different letters denote differences at the $P < 0.05$ level.

be feasible if indirect effects are observed, beyond that associated with the sole provision of energy. As an example, CSFA supplementation improved postpartum reproductive function of beef females (Hightshoe et al., 1991) and pregnancy rates of *B. indicus* (Lopes et al., 2009, 2011) and *B. taurus* (Brandão et al., 2018) beef cows.

The supplement effect observed for final BW of bulls was expected, given that intake (Mertens, 1987, 1994) and, consequently, the amount of nutrients absorbed and utilized by the animals play a pivotal role on the resulting performance of the herd. In agreement, Miorin et al. (2016) also reported greater performance in grazing animals offered a 0.7% vs. 0.2% of BW supplement during the rainy season. On the other hand, the lack of effects of CSFA fortification of supplements offered at 1.0% of BW might be related to the resulting CSFA intake. It is unknown at this point the best dose–response of CSFA in supplements to grazing ruminants, so it can be speculated that animals consuming the SP1+ supplement did not reach the expected CSFA intake to improve the performance when compared with SP1− cohorts. On the other hand, bulls offered SP03+ had a greater CSFA intake (108 vs. 62 g/d), which resulted in a greater ADG and a calculated gain/area (data not shown) compared to non-CSFA-fed cohorts. In agreement to our statement, Mosley et al. (2007) reported a positive linear response in milk production as CSFA intake increased from 0 to 500 g/cow daily.

Several factors could be involved on the observed improvement in growth performance of SP03+ and SP03− bulls, such as the aforementioned metabolic effects of fat vs. carbohydrates feedstuffs. A second factor could be related to the better utilization of lipid- vs. carbohydrate-derived energy, following the rationale presented by Hales et al. (2015, 2017). These authors suggested that in diets/supplements with an ether extract content ≥6.5% (DM basis), the metabolizable:digestible energy ratio should be greater than the current value reported in the NASEM (2016; 0.92 vs. 0.82). If this ratio suggested by Hales et al. (2015, 2017) is taken into account herein, the Metabolizable energy (ME) concentration of SP03− and SP03+ would be 2.84 and 3.24 Mcal/kg supplement, respectively. Lastly, the effects of CSFA supplementation on forage DMI of cattle grazing tropical grasses are largely unknown at this point. In lactating dairy cattle, Allen (2000) suggested that DMI reduces by 2.5% as CSFA is added to the diet. In beef cattle, forage organic matter intake was not affected by feeding supplemental unprotected fat at a rate of 1.50% to 1.74% of diet DM (Brokaw et al., 2000, 2001). Forage intake also was not affected in steers offered switchgrass hay and canola seeds to provide 4% of diet DM as fat (Leupp et al., 2006). Therefore, taking the observations by Brokaw et al. (2000, 2001) into the present study and considering a total DMI of 2% of animal BW, CSFA intake would represent 1.49% and 0.83% of diet DM for animals consuming or not CSFA, respectively, which unlikely affected forage DMI herein.

Supplement and Water Behavior Data

As expected by the experimental design, a supplement × CSFA × week interaction was observed for supplement intake ($P < 0.001$). All the statistical differences observed in the present interaction occurred on weeks 13 and 14 of the study. Bulls offered SP03− consumed more supplement than SP03+ and SP1− on week 13 (+2.9 and +2.4 kg, respectively; $P \leq 0.05$), whereas SP03− and SP03+ consumed less supplement than SP1+ on week 14 of the study (−3.06 and −4.74 kg, respectively; $P \leq 0.01$). Moreover, SP03+ consumed less supplement than SP1+ on week 13 (−3.06 kg; $P = 0.01$) and SP1− consumed less supplement than SP1+ on weeks 13 and 14 of the study (−2.51 and −3.94 kg, respectively; $P \leq 0.03$). Effects of supplement amount, CSFA fortification, and supplement × CSFA effect were not ($P \geq 0.13$) observed for supplement intake (kg/d or as % BW), number of visits to the feeder/day or I/V (Table 5). A supplement type × CSFA interaction tended ($P = 0.07$) to be observed for time spent at the feeder (Table 5). Although no differences were observed

Table 5. Supplement intake (kg/d and % of BW), visits per day, intake per visit (**I/V**) and time spent at the feeder of Nellore bulls offered DM supplementation at 0.3% or 1.0% of BW with or without CSFA fortification from days 0 to 98[1]

	SP03		SP1			*P*-value		
Item[2]	SP03−	SP03+	SP1−	SP1+	SEM	Supplement	CSFA	Supplement × CSFA
Supplement intake								
kg DM/d	1.52	1.08	2.01	2.06	0.551	0.64	0.71	0.45
% BW	0.42	0.30	0.54	0.55	0.139	0.13	0.75	0.66
CSFA intake, g/d	—	108.0	—	61.8	—	—	—	—
Visits/d	5.1	6.4	7.7	5.6	1.45	0.55	0.79	0.26
Intake/visit, kg	0.298	0.169	0.261	0.368	0.118	0.90	0.96	0.17
Time spent at the feeder, min/d	12.1[ab]	13.1[ab]	17.5[b]	9.8[a]	3.10	0.52	0.13	0.07

[ab]Within a row, means without a common superscript differ ($P < 0.05$).

[1]SP03− = supplementation of 0.3% of BW without CSFA fortification; SP03+ = supplementation of 0.3% of BW with CSFA fortification; SP1− = supplementation of 1.0% of BW without CSFA fortification; SP1+ = supplementation of 1.0% of BW with CSFA fortification.

[2]Throughout the experimental, data were collected through an electronic data capture system (Intergado; Contagem, Minas Gerais, Brazil).

for supplement intake and visits to the feeder as a result of CSFA supplementation, SP1+ bulls spent ($P = 0.05$) less time at the feeder vs. SP1− bulls, whereas no differences were observed ($P = 0.78$) between SP03− and SP03+ bulls (Table 5).

To the best of our knowledge, no other research study has evaluated the effects of CSFA supplementation for ruminants grazing warm-season grasses. The lack of difference on supplement intake between SP1 and SP03 bulls was unexpected, but can be explained by the large animal-to-animal variation and reduced supplement intake of SP1 bulls (approximately 0.55% BW). Hence, it is not surprising that the resulting CSFA intake in SP1+ bulls was compromised and impacted the overall objective of the present study. It is known that season of the year significantly impacts supplement intake, so that as moisture content of forage increases, supplement intake also increases (Bowman and Sowell, 1997). Arthington and Swenson (2004) reported greater supplement intakes as moisture of the forage increased (rainy) vs. dry season. It is noteworthy mentioning that these authors offered a mineral supplement, whereas herein a medium- to high-supplement intake was used. Hence, it can be speculated that when medium- to high-quality forages are available to the animal, endocrine factors might limit additional DMI.

Current concerns regarding beef production systems involve the improvement on performance, while maintaining the utilization of natural resources, such as land and water (FAO, 2009). Hence, it is imperative to develop strategies that meet these ultimate goals and provide enough food to a growing population worldwide. It is well-known that beef production systems require a considerable amount of water (Zanetti et al., 2019). Recently, Ahlberg et al. (2018) reported that water intake in growing cattle ranges from 8.0% to 9.8% of BW. Besides the environmental aspect of water intake and utilization by beef production systems, a more accurate estimate of this parameter would enable producers to determine water demands, and consequently, ensure water availability to the herd (Zanetti et al., 2019). Water intake is influenced by several factors, such as weather, type of diet, breed, age, BW, and physiological status of the animals (NASEM, 2016).

A CSFA × week effect tended ($P = 0.06$) to be observed for water intake, primarily because water intake was or tended to be reduced in animals receiving CSFA during weeks 4, 5, 6, and 14 of the study ($P \leq 0.10$; −3.7, −4.3, −3.6, and −1.1 liters, respectively). No supplement or CSFA effects were observed on mean average intake (liter/d), whereas bulls supplemented with CSFA tended to consume less water compared to cohorts not supplemented with CSFA (4.96% vs. 4.11% of BW, respectively; $P = 0.10$; Table 6) Moreover, no significant interactions or main effects were observed ($P \geq 0.20$) on number of visits to the water source or IPV (Table 6).

Overall, water intake data observed herein is in close agreement to values observed and reported by Zanetti et al. (2019) with *B. indicus* cattle (18.6 vs. 16.7 liters/d, respectively). Nonetheless, the present and Zanetti et al. (2019) studies significantly differ from previous reports, equations, and estimates for water intake (CSIRO, 2007; Sexson et al., 2012; NASEM, 2016), which could be related to the environment where studies that originated these equations were conducted (tropical vs. temperate), given

Table 6. Water intake (liter/d and % of BW), visits per day, IPV and time spent at the feeder of Nellore bulls offered DM supplementation at 0.3% or 1.0% of BW with or without CSFA fortification from days 0 to 98[1]

	SP03		SP1			*P*-value		
Item[2]	SP03−-	SP03+	SP1−	SP1+	SEM	Supplement	CSFA	Supplement × CSFA
Water intake								
Liter/d	18.2	19.0	19.9	17.3	1.25	0.98	0.47	0.18
% BW	5.01	4.07	4.91	4.15	0.508	0.99	0.10	0.87
Visits/d	2.4	2.5	2.6	2.3	0.15	0.94	0.54	0.30
Intake/visit, liter	7.55	7.79	7.95	7.62	0.467	0.80	0.92	0.54
Time spent at the water source, min/d	3.6	4.1	3.6	3.7	0.54	0.67	0.55	0.67

[1]SP03− = supplementation of 0.3% of BW without CSFA fortification; SP03+ = supplementation of 0.3% of BW with CSFA fortification; SP1− = supplementation of 1.0% of BW without CSFA fortification; SP1+ = supplementation of 1.0% of BW with CSFA fortification.

[2]Throughout the experimental, data were collected through an electronic data capture system (Intergado; Contagem, Minas Gerais, Brazil).

that beef production on tropics is conditioned to high temperatures, with small daily oscillation, as well as elevated humidity and precipitation (Zanetti et al., 2019). Additionally, breed differences may play a pivotal role, as such that *B. taurus* cattle often present a greater water intake than *B. indicus* cohorts (Valente et al., 2015) and most of the models and equations were derived from studies conducted with *B. taurus* herds (NASEM, 2016).

In agreement with our data, Miorin et al. (2016) also did not observe differences on time spent at water through of grazing Nellore animals offered different types of supplements during the rainy season. Moreover, it can be argued that if no differences on time spent at the water through were observed, no differences in water intake would be observed. Nonetheless, as % of BW, animals supplemented with CSFA tended to consume less water than nonsupplemented cohorts (Table 6). Zanetti et al. (2019) reported that DMI was the predictor with greatest contribution to increasing water intake. In general, a reduction in DMI is followed by a reduction in water intake (Kramer et al., 2009) and this behavior can be explained either by 1) the ruminal liquid dilution rate (Adams et al., 1981; Adams and Kartchner, 1984) or 2) the heat increment caused by fermentation and digestion (Finch, 1986). In fact, the latter factor seems to be the most reasonable to have occurred, given that the replacement of ground corn by CSFA would change the rumen fermentation dynamics and characteristics of the animals.

It is interesting to report that SP1+ bulls spent less time at the feeder compared to SP1− cohorts. One possible explanation might be related to the removal of readily fermentable feedstuffs (i.e., corn) and replacement with CSFA. It is known that CSFA do not ferment in the rumen, and hence, do not generate the same amount of heat through fermentation (NASEM, 2016). In the present study, the supplement bunk facility was covered and provided some shade to the animals, so cattle supplemented at 1.0% of BW (DM basis) would also remain more time at the facility to dissipate some heat from the environment plus the fermentation of the diet. The same behavioral effect was not observed at the water source, primarily due to the fact that the water trough was not covered and bulls would move to this location to specifically drink water.

CONCLUSIONS

To the best of our knowledge, no other research study has evaluated the effects of CSFA supplementation for growing ruminants grazing warm-season grasses. The lack of difference on supplement intake between SP1 and SP03 bulls was unexpected, but can be explained by the large animal-to-animal variation and reduced supplement intake of SP1 bulls (approximately 0.55% BW). Hence, it is not surprising that the resulting CSFA intake in SP1+ bulls was compromised and impacted the overall objective of the present study. Nonetheless, CSFA fortification into 0.3% of BW supplements increased ADG compared to nonsupplemented cohorts and water intake (as % BW) tended to be reduced in animals offered CSFA, demonstrating a potential for this technology to increase the performance of the herd while maintaining the utilization of the natural resources required for beef cattle production.

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LITERATURE CITED

Adams, D. C., M. L. Galyean, H. E. Kiesling, J. D. Wallace, and M. D. Finkner. 1981. Influence of viable yeast culture, sodium bicarbonate and monensin on liquid dilution rate, rumen fermentation and feedlot performance of growing steers and digestibility in lambs. J. Anim. Sci. 53:780–789. doi:10.2134/jas1981.533780x

Adams, D. C., and R. J. Kartchner. 1984. Effect of level of forage intake on rumen ammonia, pH, liquid volume and liquid dilution rate in beef cattle. J. Anim. Sci. 58:708–713. doi:10.2134/jas1984.583708x

Ahlberg, C. M., K. Allwardt, A. Broocks, K. Bruno, L. McPhillips, A. Taylor, C. R. Krehbiel, M. S. Calvo-Lorenzo, C. J. Richards, S. E. Place, et al. 2018. Environmental effects on water intake and water intake prediction in growing beef cattle. J. Anim. Sci. 96:4368–4384. doi:10.1093/jas/sky267.

Allen, M. S. 2000. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. J. Dairy Sci. 83:1598–1624. doi:10.3168/jds.S0022-0302(00)75030-2

Allen, T. E., J. W. Bennettf, S. M. Donegan, and J. C. D. Hutchinson. 1970. Moisture, its accumulation and site of evaporation in the coats of sweating cattle. J. Agric. Sci. 74:247–258. doi:10.1017/S0021859600022863

AOAC. 2006. Official methods of analysis. 18th ed. Arlington, VA: Assoc. Off. Anal. Chem.

Arthington, J. D., and C. K. Swenson. 2004. Effects of trace mineral source and feeding method on the productivity of grazing Braford cows. Prof. Anim. Sci. 20:155–161. doi:10.15232/S1080-7446(15)31290-0

Barducci, R. S., L. M. N. Sarti, D. D. Millen, T. C. Putarov, F. A. Ribeiro, M. C. S. Franzói, C. F. da Costa, C. L. Martins, and M. B. Arrigoni. 2015. Fatty acids on the performance and immune responses of Nellore feeder cattle. Pesq. Agropec. Bras. 50:499–509. doi:10.1590/S0100-204X2015000600009

Batistel, F., J. de Souza, and F. A. P. Santos. 2017. Corn grain-processing method interacts with calcium salts of palm fatty acids supplementation on milk production and energy balance of early-lactation cows grazing tropical pasture. J. Dairy Sci. 100:5343–5357. doi:10.3168/jds.2016-12503.

Bowman, J. G., and B. F. Sowell. 1997. Delivery method and supplement consumption by grazing ruminants: a review. J. Anim. Sci. 75:543–550. doi:10.2527/1997.752543x.

Brandão, A. P., R. F. Cooke, K. M. Schubach, R. S. Marques, D. W. Bohnert, R. S. Carvalho, N. W. Dias, C. L. Timlin, S. Clark-Deener, J. F. Currin, et al. 2018. Supplementing Ca salts of soybean oil after artificial insemination increases pregnancy success in *Bos taurus* beef cows. J. Anim. Sci. 96:2838–2850. doi:10.1093/jas/sky156.

Brokaw, L., B. W. Hess, and D. C. Rule. 2001. Supplemental soybean oil or corn for beef heifers grazing summer pasture: effects on forage intake, ruminal fermentation, and site and extent of digestion. J. Anim. Sci. 79:2704–2712. doi:10.2527/2001.79102704x.

Brokaw, L., B. W. Hess, A. D. Schleicher, E. J. Scholljegerdes, L. M. Yun, J. D. Hegg, and J. Bratka. 2000. Evaluation of supplemental high oil corn for heifers grazing summer pasture. Proc. West. Sect. Am. Soc. Anim. Sci. 51:290–294.

Chizzotti, M. L., F. S. Machado, E. E. Valente, L. G. Pereira, M. M. Campos, T. R. Tomich, S. G. Coelho, and M. N. Ribas. 2015. Technical note: validation of a system for monitoring individual feeding behavior and individual feed intake in dairy cattle. J. Dairy Sci. 98:3438–3442. doi:10.3168/jds.2014-8925.

CSIRO. 2007. Nutrient requirements of domesticated ruminants. CSIRO Publishing: Camberra, AU.

Detmann, E., M. F. Paulino, S. C. Valadares Filho, and P. Huhtanen. 2014. Nutritional aspects applied to grazing cattle in the tropics: a review based on Brazilian results. Semin. Ciências Agrar. 35:2829–2854. doi:10.5433/1679-0359.

FAO. 2009. The state of food and agriculture. Rome, Italy: Published by Food and Agricultural Organization of the United Nations; p. 53–63.

FASS. 2010. Guide for the care and use of agricultural animals in agricultural research and teaching, 3rd ed. Savoy, IL: Federation of Animal Science Societies.

Fieser, B. G., G. W. Horn, and J. T. Edwards. 2007. Effects of energy, mineral supplementation, or both, in combination with monensin on performance of steers grazing winter wheat pasture. J. Anim. Sci. 85:3470–3480. doi:10.2527/jas.2007-0127.

Finch, V. A. 1986. Body temperature in beef cattle: its control and relevance to production in the tropics. J. Anim. Sci. 62:531–542. doi:10.2134/jas1986.622531x

Goering, H. K., and P. J. Van Soest. 1970. Apparatus, reagents, procedures and some applications. In. Forage fiber analysis, agriculture handbook no. 379. Washington: USDA; p. 387–598.

Hales, K. E., A. P. Foote, T. M. Brown-Brandl, and H. C. Freetly. 2015. Effects of dietary glycerin inclusion at 0, 5, 10, and 15 percent of dry matter on energy metabolism and nutrient balance in finishing beef steers. J. Anim. Sci. 93:348–356. doi:10.2527/jas2014-8075

Hales, K. E., A. P. Foote, T. M. Brown-Brandl, and H. C. Freetly. 2017. The effects of feeding increasing concentrations of corn oil on energy metabolism and nutrient balance in finishing beef steers. J. Anim. Sci. 95:939–948. doi:10.2527/jas2016.0902

Hess, B. W., G. E. Moss, and D. C. Hule. 2008. A decade of developments in the area of fat supplementation research with beef cattle and sheep. J. Anim. Sci. 86:E188-204. doi:10.2527/jas.2007-0546

Hightshoe, R. B., R. C. Cochran, L. R. Corah, G. H. Kiracofe, D. L. Harmon, and R. C. Perry. 1991. Effects of calcium soaps of fatty acids on postpartum reproductive function in beef cows. J. Anim. Sci. 69:4097–4103. doi:10.2527/1991.69104097x.

Kramer, E., E. Stamer, J. Spilke, G. Thaller, and J. Krieter. 2009. Analysis of water intake and dry matter intake using different lactation curve models. J. Dairy Sci. 92:4072–4081. doi:10.3168/jds.2008-1957.

Leupp, J. L., G. P. Lardy, S. A. Soto-Navarro, M. L. Bauer, and J. S. Caton. 2006. Effects of canola seed supplementation on intake, digestion, duodenal protein supply, and microbial effiiciency in steers fed forage-based diets. J. Anim. Sci. 84:499–507. doi:10.2527/2006.842499x.

Lopes, C. N., R. F. Cooke, M. M. Reis, R. F. Peres, and J. L. Vasconcelos. 2011. Strategic supplementation of calcium salts of polyunsaturated fatty acids to enhance reproductive performance of *Bos indicus* beef cows. J. Anim. Sci. 89:3116–3124. doi:10.2527/jas.2011-3909.

Lopes, C. N., A. B. Scarpa, B. I. Cappellozza, R. F. Cooke, and J. L. Vasconcelos. 2009. Effects of rumen-protected polyunsaturated fatty acid supplementation on reproductive performance of *Bos indicus* beef cows. J. Anim. Sci. 87:3935–3943. doi:10.2527/jas.2009-2201.

McDowell, L. R., and J. D. Arthington. 2005. Minerals for grazing ruminants in tropical regions. Mosaic. 4:86.

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64:1548–1558. doi:10.2527/jas1987.6451548x.

Mertens, D. R. 1994. Regulation of forage intake. In: Fahey, G. C., Jr., M. Collins, D. R. Mertens, and L. E. Moser, editors, Forage quality, evaluation, and utilization. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America; p. 450–493.

Minson, D. J. 1990. Forage in ruminant nutrition. San Diego: Academic Press; p. 483.

Miorin, R. L., R. M. Saad, L. D. Silva, S. Galbeiro, U. Cecato, and F. L. Junior. 2016. The effects of energy and protein supplementation strategy and frequency on the performance of beef cattle that grazed on Tanzania grass pastures during the rainy season. Trop. Anim. Health Prod. 48:1561–1567. doi:10.1007/s11250-016-1128-0.

Mosley, S. A., E. E. Mosley, B. Hatch, J. I. Szasz, A. Corato, N. Zacharias, D. Howes, and M. A. McGuire. 2007. Effect of varying levels of fatty acids from palm oil on feed intake and milk production in Holstein cows. J. Dairy Sci. 90:987–993. doi:10.3168/jds.S0022-0302(07)71583-7

NASEM. 2016. National Academies of Sciences, Engineering, and Medicine. Nutrient requirements of beef cattle model, 8th rev. ed. Washington, DC: National Academic Press.

Pinto, A. C. J., and D. D. Millen. 2019. Nutritional recommendations and management practices adopted by feedlot cattle nutritionists: the 2016 Brazilian survey. Can. J. Anim. Sci. 99:392–407. doi:10.1139/cjas-2018-0031.

Rosa, B. L., A. A. M. Sampaio, W. Henrique, E. A. Oliveira, T. M. Pivaro, A. T. Andrade, and A. R. M. Fernandes. 2013. Performance and carcass characteristics of Nellore young bulls fed different sources of oils, protected or not from rumen degradation. R. Bras. Zootec. 42:109–116. doi:10.1590/S1516-35982013000200005

Sexson, J. L., J. J. Wagner, T. E. Engle, and J. Eickhoff. 2012. Predicting water intake by yearling feedlot steers. J. Anim. Sci. 90:1920–1928. doi:10.2527/jas.2011-4307.

Valente, E. E. L., M. L. Chizzotti, C. V. R. Oliveira, M. C. Galvao, S. S. Domingues, A. C. Rodrigues, and M. M. Ladeira. 2015. Intake, physiological parameters and behavior of Angus and Nellore bulls subjected to heat stress. Semin Cienc. Agrar. 36:4565–4574. doi:10.5433/1679-0359.2015v36n6Sup2p4565

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597. doi:10.3168/jds.S0022-0302(91)78551-2

Weiss, W. P., H. R. Conrad, and N. R. St. Pierre. 1992. A theoretically-based model for predicting total digestible nutrient values of forages and concentrates. Anim. Feed Sci. Technol. 39:95–110. doi:10.1016/0377-8401(92)90034-4

Zanetti, D., L. F. Prados, A. C. B. Menezes, B. C. Silva, M. V. C. Pacheco, F. A. S. Silva, L. F. Costa E Silva, E. Detmann, T. E. Engle, and S. C. Valadares Filho. 2019. Prediction of water intake to *Bos indicus* beef cattle raised under tropical conditions1. J. Anim. Sci. 97:1364–1374. doi:10.1093/jas/skz003